Process Evaluation Section

Separation and Recovery of Carbon Dioxide From Fossil-Fuel-Fired Electric Power Plants

Background

A large number of natural gas discoveries are not Fossil-fuel-fired electric power plants in the U.S. emit about 2 billion tons of the greenhouse gas CO_2 into the air every year. Avoiding emissions of CO_2 to the atmosphere is receiving increasing attention because such emissions are expected to contribute to future climate change via the Greenhouse Effect. Working with the Massachusetts Institute of Technology Energy Lab we conducted a technical and economic assessment of several technologies that could be used to separate and recover CO_2 from the flue-gas of fossil-fuel-fired utility boilers. The technologies include chemical solvent, cryogenic, membranes, physical absorption and physical adsorption methods. Many of these technologies have traditionally been used for acid gas clean-up, CO_2 recovery for enhanced oil recovery, and CO_2 capture for use in the beverage industry. We evaluated these technologies to see if they would be appropriate for capturing CO_2 from the flue gas of power plants and at what conditions and the impact they will have on the power generation efficiency and cost. Research needs for the various processes were identified to minimize the impact of each option on the overall efficiency and cost of power generation.

Approach and Results

For each of these technologies we developed conceptual designs for their integration with the coal-fired power plants and performed thermodynamic analysis on the integrated system to determine the material and energy flows. We also assessed the impact of each on the cost of power generation. We then identified potential modifications and improvements that will make the separation technology more suitable for this application. The results of the investigation showed that each of these methods would result in nearly doubling of the cost of power generation and in more than a 30% reduction in net power output.

Therefore, we investigated two potential strategies for modifying the combustion process itself to make the CO_2 recovery more economical and less energy intensive. These are: (a) combustion of fuels in O_2 with CO_2 recycle, yielding a mixture that is primarily H_2O and CO_2, from which water can be easily separated, and (b) elimination of the carbon from the fuels before combustion. The first of these requires air separation to produce O_2 for combustion. It is also costly and energy intensive. However, we estimated that it costs \$10-\$15 less to recover CO_2 by this method than by the conventional methods for separating the CO_2 from the flue-gas that contains N_2. This process would even be more attractive if O_2 can be produced at a lower cost than what the state of the art allows. Therefore, we investigated chemical cycles (Barium Oxide/Peroxide cycle and the Nitrate/ Nitrite cycle) to separate O_2 from air. Energy wise, these look specially promising when integrated with high temperature power cycles.

The second concept, elimination of the carbon from the fuels before combustion, involves thermal cracking of the coal and separating the solid carbon from the hydrogen gas. The hydrogen can be burned using air and the carbon can either be sequestered as a solid or burned with oxygen and the CO_2 is recovered without requiring separation. If the carbon is not to be used as a fuel, the energy loss will be significant.

Publications

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